Semi-Annual Progress Report

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Task Objectives

The objectives of the last six months were:

Conduct sensitivity analysis of fluorescence line height algorithms

Continue to review plans for EOSDIS and assist ECS contractor

Participate in Multi-Sensor Ocean Color Workshop in Miami

Analyze bio-optical data from Southern Ocean cruise

Prepare for laboratory experiments based on analyses of field data

Deploy bio-optical mooring off Hawaii.

Work Accomplished

- Project Data and Information System Plans

Data Flow Diagrams

I developed a data flow diagram for Fluorescence Line Height (FLH) and Chlorophyll Fluorescence Efficiency (CFE) algorithms in response to a request from Ed Masuoka. This also included descriptions of quality flags, data layout, etc. A copy also was sent to Robert Evans (Univ. Miami).

- Local Scientific Compute Facilities

Advanced Networking

A proposal was made to HITC to support development of SCF to SCF links to test the software and hardware requirements for interdisciplinary research. Specific deliverables and schedules have been finalized, and the contract should begin this fall. This will involve a collaboration with Berrien Moore (UNH).

Information Systems Development

Our Microsoft SQL Server data base serves as our primary information management system. We have developed Windows, Macintosh, and UNIX clients to access our satellite and in situ data. We have continued to extend our Mosaic client to allow for map-based searches for data of interest. A Silicon Graphics workstation was purchased which included the SGI "WebForce" product for Mosaic authoring. This has greatly simplified this process.

We are awaiting the release of SQL Server 6.0 which will include Object Linking and Embedding (OLE) capabilities. This will allow direct connections between OLE-compliant desktop applications and the data base. With the imminent release of Windows 95, more applications will become OLE-compliant.

Hardware Configuration

We will soon order a large disk array to complement our Silicon Graphics Power Challenge XL that was purchased using EOS interdisciplinary funds. The disk array will have 100 GB of high performance disk, We continue to rely on a mixed environment of PC's and UNIX workstations to support our data management and algorithm development,

Future Directions

As discussed above, we will continue to enhance the functionality of the present system as new operating system features become available, The number of applications that support OLE and ODBC is increasing, and we will rely on this capability to link applications and the data management system, We are continuing to develop our OLE-based framework for data management and analysis.

- Data Analysis and Interpretation

Journal Publications

Our paper on bio-optical drifters has finally been published in *Journal of Geophysical Research,* and a reprint is enclosed, Two manuscripts have been submitted for publication. The complete manuscripts are enclosed. The first is a sensitivity analysis of MODIS for measuring chlorophyll fluorescence and has been submitted to *Remote*

Sensing of the Environment.. Considering realistic scenarios and given the present specifications of MODIS bands 13, 14, and 15, we are confident that the FLH algorithm will permit the detection of 1 mg chlorophyll m^{-3} changes in the surface of the ocean. Under optimum viewing conditions, this level can be decreased to 0.5 mg m^{-3}. More oligotrophic regions of the ocean may be studied using FLH if 4 by 4 pixels are averaged together to increase the effective SNR. In this case, the minimum sensitivity improves to 0.13 mg chlorophyll m^{-3}. This sets the minimum chlorophyll concentration under which FLH retrievals can be made. However, we are also interested in the response of the FLH algorithm to changes in chlorophyll concentration. Given the present specifications of MODIS bands 13, 14, and 15, the FLH algorithm sensitivity could be increased by 20% if the center wavelength of band 14 is shifted to 680 nm from its present position at 676.7 nm.

The FLH algorithm relies on precise band placement to avoid absorption features in the atmosphere as well as to resolve chlorophyll absorbance and fluorescence in the ocean. Subtle shifts in band placement can have a significant impact on the performance of the FLH algorithm. Using chlorophyll concentrations of 10 mg m^{-3}, we calculated the resulting ocean surface exitance spectrum. This spectrum was propagated through the atmosphere using LOWTRAN. Shifts of 4 nm in individual MODIS bands resulted in changes in TOA radiances of less than 2% in individual band performance. However, The FLH absolute signal can be modified by more than 70%. This effect is smaller if bands are shifted the same amount as a group. Changes in band position in the MODIS instrument are more likely to move bands as a group, rather than move individual bands.

The signal to noise ratio is negatively correlated with atmospheric turbidity and the sensitivity of the FLH signal may vary 3 fold as a result of changes in atmospheric aerosol content, Despite the effects of atmospheric variability, the magnitude of the FLH signal per unit chlorophyll is more dependent on the fluorescence quantum yield of chlorophyll.

The most significant challenge will be the interpretation of FLH data. Assuming that instrument performance and atmospheric variations can be quantified, then variations in the physiological response of the phytoplankton as manifested in their quantum efficiency of fluorescence will be the most important obstacle. However, if chlorophyll concentrations can be estimated independently using radiance ratios, then the variations in FLH over time may be used to derive estimates of quantum efficiency and hence improve models of primary productivity. The next step is to conduct detailed laboratory and field studies to pursue the relationship between FLH and productivity.

The second manuscript is a short description of bio-optical drifter deployments in the Southern Ocean and has been submitted to the *Antarctic Journal of the U.S.* A copy of the manuscript is enclosed. One of the drifters became trapped in a cyclonic eddy for

40 days, These data are especially useful for studying the response of chlorophyll fluorescence to changes in solar irradiance and nutrient stress.

Analysis of Ocean Drifter Data

All of the bio-optical drifters in the California Current have now failed, with the last one disappearing in late June, 10 months after deployment. These data are now being processed. We have made preliminary calculations of the Lagrangian statistics of the physical data (currents and temperature). There is a strong seasonal dependence, with length and time scales becoming shorter in winter and spring. We have developed routines for flagging contaminated data in the bio-optical measurements and are beginning to calculate statistics for these fields as well.

Laboratory Experiments

Ricardo Letelier will visit with Dr. Paul Falkowski (Brookhaven National Laboratory) in July to conduct experiments on fluorescence and quantum yield. Our analysis of the drifter data suggests that evaluating fluorescence yield as a function of downwelling irradiance may provide an estimate of the light saturation level for phytoplankton. If this parameter can be estimated from satellites, then our ability to estimate primary productivity will be greatly increased. Letelier has designed experiments with laboratory cultures to test this hypothesis, This result, though tentative, is perhaps the most exciting development of this project. Present models of productivity based on fluorescence are designed for light-limited phytoplankton. Since MODIS will be observing communities near the ocean surface at light saturation, this promising result could be a breakthrough for satellite-based estimates of productivity. If the experiments are successful, Letelier will present them at the Tenth international Symposium on Photosynthesis in Montpelier, France, this August.

We are still awaiting the arrival of our Fast Repetition Rate Fluorometer. The manufacturer has transferred all orders to another company (Chelsea Instruments) which has far more experience with oceanographic equipment, However, this has delayed our laboratory studies as the FRR fluorometer is a key element of this study of the relationship between fluorescence yield and quantum efficiency,

Bio-optical Mooring

We deployed our bio-optical mooring (paid for primarily by EOS interdisciplinary funds) at the Hawaii Ocean Time-series station off Hawaii in May. The mooring consisted of a Satlantic spectroradiometer, a small current meter, and data logger. The total mooring cost approximately $15,000. The test mooring worked successfully. Irradiance ratios were used to estimate chlorophyll, and values were within the expected range for the HOT site. Although the mooring performed well during this test, current speeds were higher than expected during the latter part of the deployment

(greater than 35 cm s^{-1}), There was some “blowover” of the sensor package, but when current speeds were within the design requirements, the optical package performed as expected and stayed within the mixed layer. We are proposing to deploy an array of these moorings during the Joint Global Ocean Flux Study in the Southern Ocean.

- Multi-Sensor Ocean Color Workshop

Both Letelier and Abbott participated in this workshop at the University of Miami. The workshop produced a plan to develop the infrastructure necessary to share ocean color data amongst the several nations planning to launch ocean color sensors. This plan includes a strategy for calibration/validation, algorithm development, data systems, and joint in situ measurements. The ultimate goal is to combine these data sets into a comprehensive time series of ocean color suitable for climate research. The plan is now being reviewed by NASA Headquarters.

Anticipated Future Actions

We will complete our analysis of the bio-optical drifter data from the California Current. A more complete analysis of the Southern Ocean deployments will also be undertaken. We will conduct laboratory experiments on fluorescence and photosynthesis. Our main emphasis is to improve our understanding of the processes driving variability in fluorescence yield and how they might be related to productivity.

We will continue to work data system issues with the Team Leader and with the ECS contractor. Our present data management and analysis system will continue to expand to take advantage of new capabilities in the operating systems.

Problems and Solutions

The only significant problem has been unforeseen delays in receiving the Fast Repetition Rate fluorometer. The original manufacturer was unable to produce the system and has recently transferred all orders to a more experienced company, Chelsea Instruments.